# Analysis of Transportation Carbon Emissions in Xinjiang Based on the Carbon Emission Factor Method for Load Weights

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**Abstract.** This study analyzes the carbon emissions of trucks at the Xinjiang G30 Yandun Toll Station using the 'Carbon Emission Factor Corresponding to Load Weight' measurement method. The Analysis includes a comparison of emissions between different types of trucks and at different times over a year. The Analysis reveals that heavy-duty trucks are the most significant source of carbon emissions, accounting for 90% and 97% of the total number of vehicles and carbon emissions, respectively. March has the highest growth rate, while June has the highest carbon emissions. This study provides data to support the region's development of a low-carbon economy. This is important for responding to the dual-carbon policy and developing a green economy.

**Keywords:** Carbon emission factor method, carbon emission, load capacity

## 1 INTRODUCTION

### 1.1 Background of the study

In 2019[1], GCP released data showing that China surpassed the United States as the world's highest carbon emitter, with over 14.1 billion tons emitted (as shown in Figure 1), accounting for approximately 28% of global emissions. China now faces the challenge of reducing its carbon emissions. (Note: No changes were made to the original text.) The central government has proposed a new concept of development and goal orientation for realizing dual-carbon work. This concept emphasizes the full implementation of efforts to solve the outstanding problems of resource and environmental constraints to achieve sustainable development for the Chinese nation.


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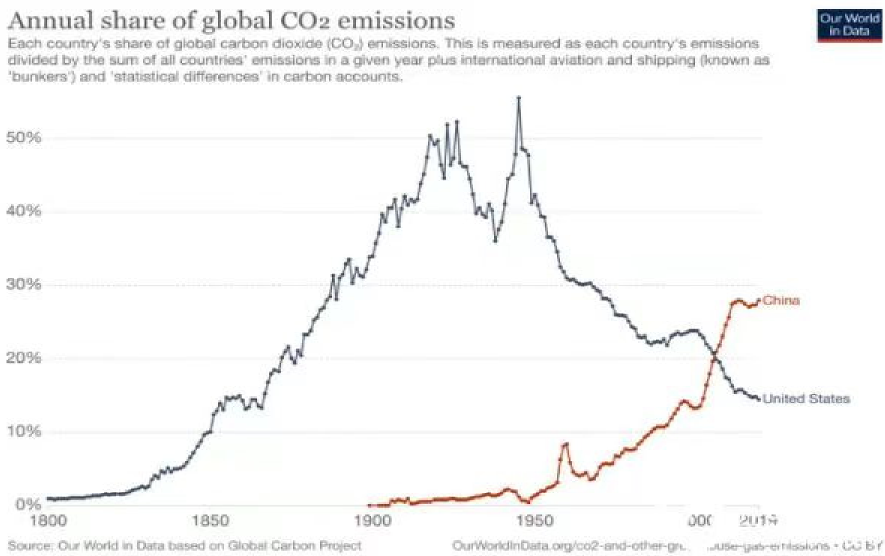


**Fig. 1.** Carbon emission data curve

The transportation sector significantly contributes to carbon emissions in China and globally. According to data released by China's National Bureau of Statistics in 2021[2], carbon emissions from transportation already account for over 8% of China's total carbon emissions (see Figure 2). However, road transportation accounts for 79.15% of emissions in the transportation industry. Therefore, there is significant potential for improving energy efficiency and reducing carbon emissions in the highway network, which is widely dispersed across various cities. The transportation industry in Xinjiang has undergone significant development in recent years, which aligns with the region's economic growth. However, this growth has come at a cost, with a dramatic increase in carbon dioxide emissions. According to a research report from the Xinjiang Institute of Ecology and Geography, total carbon emissions and per capita carbon emissions from the transportation industry in Xinjiang have risen at a high rate since 1989[3], with an average annual growth rate of 10.8% and 9.1%, respectively. Exploring transportation carbon emissions in Xinjiang and finding solutions is significant to local energy conservation, environmental protection, and economic development. Xinjiang is an important trade hub for China's import and export and energy supply. Truck transportation accounts for over 70% of the transportation industry. Analyzing the carbon emissions data from trucks in Xinjiang under different circumstances can better promote the development of the local low-carbon economy.

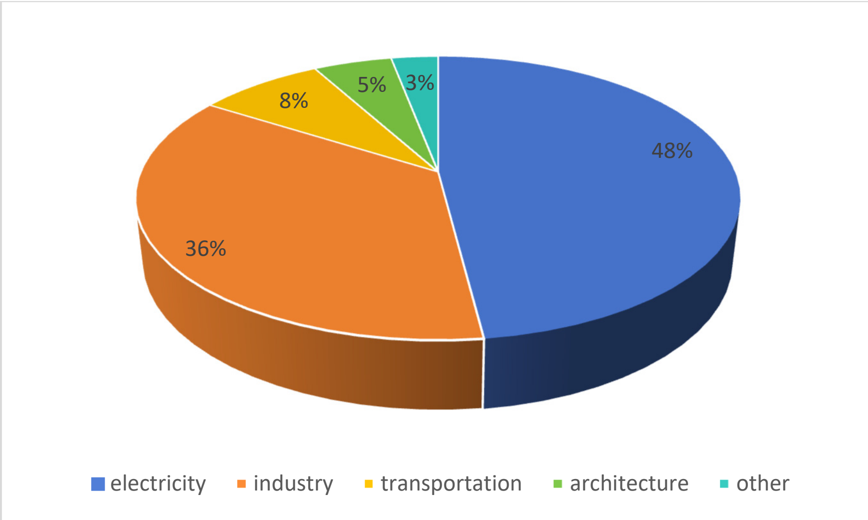


**Fig. 2.** Distribution of Carbon Emissions by Sectors as a Percentage

### 1.2 Current status of domestic and international research

Mai Le et al. utilized the system dynamics approach to measure and study the energy consumption and carbon emissions of transportation in China[4]. They improved the calculation of carbon emissions. Han Shuwan et al. also researched carbon emissions in China. The GDIM model was utilized for the first time to decompose carbon emissions from transportation and highways and simulate future carbon emission trends in the three northeastern provinces. Dong Jun, Deng Chun, et al. [5] analyzed the carbon emissions of Xinjiang's transportation sector and the factors that influence them using the STIRPAT regression model. [6]Li, Minquan Ji, et al. also conducted a similar analysis. The LMDI model was utilized to analyze carbon emissions from transportation in the Sanjiangyuan region, and the resulting trends were predicted [7]. Shi Shuang et al. constructed a mathematical model using SDA analysis to analyze the factors of carbon transfer from various aspects and measured the intensity of direct carbon emissions [8]. Stefan Gossling et al. [9] and Shi Peihua [10] also conducted similar studies. The carbon emissions from transportation were estimated using the IPCC subsectoral calculation method. Bin & Dowlatabadi[11] et al. used the more accurate IPCC-specific emission factor method to estimate local transportation carbon emissions. Wine and V[12] found that temperature changes directly affect automobile carbon emissions under the same conditions. The studies above reveal that measuring carbon emissions is constrained by various external factors. Different spaces are affected by distinct climates, temperatures, and other factors. This paper will primarily concentrate on the impact of time and car models on carbon emissions.

### 1.3 Purpose of the study

The issue of carbon emissions in transportation primarily concerns road transportation. This paper examines the carbon emissions of different types of trucks on the G30 Yandun Toll Station road section. The study primarily uses carbon emission factors to measure the data and analyzes the differences in emissions from different sources during different months. This paper's research can provide relevant departments in various regions with a theoretical basis and reference ideas for realizing the dual-carbon plan, thereby promoting the development of a low-carbon economy.

## 2 DATA AND METHODS FOR MEASURING CARBON EMISSIONS

### 2.1 Data content

The paper utilizes precise data, such as the number of axles, load capacity, inbound time, and vehicle type, of trucks passing through the Xinjiang Yandun Expressway Toll Station to the adjacent toll station, Erbao Mainline Toll Station, provided by the Xinjiang Expressway Database. In the later stage, the data obtained is processed. Any abnormal vehicle parameter values and their corresponding data are deleted. The remaining data is integrated and counted to ensure its reliability and multidimensionality.

### 2.2 Comparison of carbon emission measurement methods

Measuring carbon emissions from vehicles in the transportation sector is a complex process with various methods, each with unique characteristics and corresponding scenarios. Some more established methods for measuring carbon emissions include the 'top-down method,' 'bottom-up method,' 'IPCC guideline method,' 'decoupling model,' 'carbon modeling,' and the 'Carbon Emission Factor Method' (as shown in Table 1). It is essential to use precise terminology when referring to these methods. Some more established methods for measuring carbon emissions include the 'top-down method,' 'bottom-up method,' 'IPCC guideline method,' 'decoupling model,' 'carbon modeling,' and the 'Carbon Emission Factor Method' (as shown in Table 1). (Table 1) The carbon emission factor method is a widely recognized approach for measuring the carbon emissions of trucks from the Yandun Toll Plaza to the Erbao Mainline Toll Plaza. This method is based on the guidelines of the International Panel on Climate Change (IPCC) and was chosen due to its unique standardization characteristics and data traceability.

**Table 1.** Comparison of different carbon emission measurement methods

| Methods of measurement | vintage | drawbacks | Bibliography |
|---|---|---|---|

| | | | |
|---|---|---|---|
| "Top-down" approach | Characterized by easy data availability and simple calculation methods | It simplifies the hypothetical method by ignoring the combustion efficiency error of the fuel that exists in actual operation. | Zhang Han, Qiu Jingning, etc. [13] Qiu Yuejin,Li Dongming et al.[14] |
| "Bottom-up" approach | Higher accuracy of calculations to characterize mobile source emissions | Higher uncertainty in calculation results and higher difficulty in obtaining primary data | Wu Cuifang, Xiong Jinhui et al.[15] Qu Xinming,Qiu Jiandong et al.[16] |
| The "IPCC Guidelines" Act | Have a certain degree of scientific validity and authority and have harmonized and standardized criteria. | Highly data-demanding and of considerable computational complexity | Li Xiaoyi,Wu Rui et al.[17] Lu Yashang, Wang Ying, et al.[18] |
| Decoupling model | Extremely flexible and practical | Highly data-demanding and model complexity. | Zhang Baofeng (1900-1978), Mao Zedong's second wife[19] SONG Xu, JIA Junsong et al. [20] |
| Carbon Emission Factor Approach | Easy to understand and operate with proven techniques and methodologies | Relatively high uncertainty and limited applicability | IPCC [21] Wang Haikun, Zhang Rongrong et al.[22] |

This paper mainly uses the 'Carbon Emission Factor Corresponding to Load Weight Method' to account for carbon emissions based on the different carbon emission factors. It also discusses corresponding controls for different months.

The 'Carbon Emission Factor Corresponding to Load Weight Method' calculates carbon emissions using the carbon emission factor corresponding to the load weight, actual load weight of the truck, and actual distance traveled. Factors affecting the results during the measurement process include the accuracy of load weight data, universality of selected regions, and applicability of selected carbon emission factor data to different situations. The accuracy of the load data, the universality of the selected region, and the applicability of the selected carbon emission factor data to different situations are all factors that affect the results. In this experiment, we used accurate data sources and a region with a certain degree of reference. Therefore, we measured carbon emissions using the 'Carbon Emission Factor Corresponding to Load Weight Method.'

### 2.3 Measurement steps for carbon emission factors

The main steps in the method of measuring the carbon emission factor corresponding to the combined load weight are as follows:

In the first step, vehicles are categorized according to their load capacity into four main categories: micro vans, minivans, medium-sized vans, and large vans.

In the second step, according to the classification of trucks, the "Carbon Emission Factor Method for Load Weight" mentioned above was used to measure the trucks separately.

In the third step, the results of this measurement are analyzed

In the fourth step, the trucks will be categorized according to their carbon emissions in different months after the breakdown.

In the fifth step, identify the particular values for different types of trucks under different months and analyze the reasons for them

In the sixth step, analyze the trend of different types of trucks based on the change curves of the study months.

# 3 MEASUREMENT OF CARBON EMISSIONS

## 3.1 Measurement of the "Carbon Emission Factor Method for Load Weight"

The formulas to be used for the "Carbon Emission Factor Method for Load Weight" are as follows:

$$C_{a,b,c,d} = Q \times EF_{a,b,c,d} \times D \tag{1}$$

$$C = \sum_{a,,b,c,d} C_{a,b,c,d} \tag{2}$$

Where C denotes the sum of the carbon emissions of the vehicles (kg) and$C_{a,b,c,d}$ denotes the carbon emissions of individual vehicles of different types (kg) and$EF_{a,b,c,d}$ denotes the carbon emission factor corresponding to that kind of vehicle ($KgCO_2$ (t-km)), D denotes the distance traveled by the vehicle (km), and Q denotes the vehicle's load capacity (t). Among them, the distance traveled by the vehicle is obtained by measuring the distance between Xinjiang Yandun Expressway Toll Station and the adjacent toll station Erbao Mainline Toll Station; the corresponding carbon emission factors of the four different models are obtained by inquiring the "Carbon Dioxide Emission Factors of Road Traffic in China's Sub-Provinces" (e.g., Table 2)[23] The effective driving distance between G30 Yandun Toll Station and Erbao Toll Station is 130km, which is calculated through the preliminary research.

**Table 2.** Carbon emission factors for each vehicle type in Xinjiang

| | Minivan | Truck, light | Truck, me dium | Truck, Heavy |
|---|---|---|---|---|
| Carbon emission factor corresponding to the vehicle ($KgCO_2$ (t-km)) | 0.121 | 0.084 | 0.043 | 0.049 |

### 3.1.1 Measurement results of the "Carbon Emission Factor Method for Load Weight"

The carbon emissions of small, medium, and large vans on the road section were calculated using the relevant formulae listed previously, as shown in Table 3.

**Table 3.** Carbon Emissions by Number of Vehicles of Each Type of Trucks

| Type of truck | Number of vehicles (vehicles) | Average load capacity (kg) | Carbon emissions (kg) |
|---|---|---|---|
| Truck, light | 88357.00 | 876.23 | 2851946.23 |
| Truck, medium | 88276.00 | 4536.41 | 5482939.00 |
| Truck, Heavy | 2299985.00 | 34879.44 | 412592022.10 |

### 3.1.2 Analysis of measurement results

In the section between G30 Yandun Toll Station and G30 Erbao Toll Station, minivans have the lowest average weight and carbon emissions, while heavy-duty trucks have the highest average weight and carbon emissions, which are much larger than those of the other three types of trucks. The data shows a direct positive relationship between the number of classified trucks and vehicles and the amount of carbon emissions, number of vehicles, and average weight. This is illustrated in Figure 3, which presents a pie chart. The load capacity of a vehicle is determined by its model, while the number of trucks is influenced by the region's geographic location and the Lianhuo Expressway's commercial value. As a crucial transportation corridor for inland trade, the Lianhuo Expressway is significant in the region's economic development. It connects the Northwest to the eastern seaboard of China, making it an essential highway for promoting trade in the Lianlu region.

Moreover, it is of great significance for both international trade and trade of landlocked countries. Furthermore, due to the 'Belt and Road' development strategy, the Lianhuo Expressway is a crucial transportation channel, often called the modern 'Silk Road,' for transporting significant energy resources such as coal, oil, and natural gas. As a result, the traffic volume on this highway has increased significantly due to its commercial value.

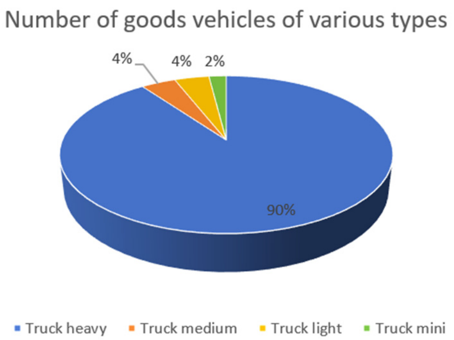


**Fig. 3.** Pie chart of the number of vehicles of various types of trucks

### 3.1.3 Analysis of the degree of variation of carbon emissions under different months

The total carbon emissions of different types of trucks under different months were integrated and plotted on a bar chart, as shown in Figure 4.

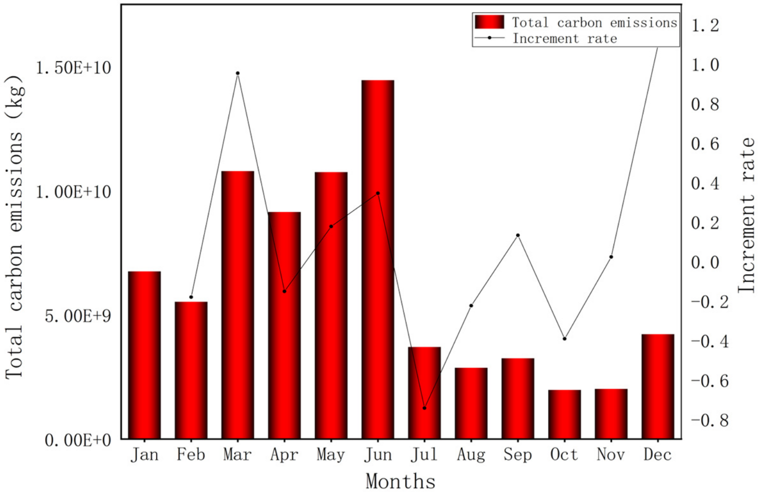


**Fig. 4.** Carbon emissions in different months

The bar chart in Figure 4 shows the total carbon emissions of each type of truck per month, based on the calculated carbon emissions of different truck types. The chart indicates a growth trend. June has the highest carbon emissions due to increased business activities, logistics operations, express delivery demand, and rising temperatures. Additionally, Xinjiang, an important energy exporting region, experiences a significant increase in the transportation of energy substances and related materials by trucks. However, there was a significant increase in carbon emissions during the month. October has the lowest carbon emissions of the year due to fewer commercial activities and cooler weather, resulting in reduced demand for energy-consuming household appliances like air conditioners and transportation of energy materials.

According to Figure 4, carbon emissions grew at a faster rate in March compared to February. This is due to the fact that during February, many logistics companies were closed for the winter vacation and Chinese New Year, resulting in a decrease in the number of trucks on the road. However, when all logistics companies resumed their normal operations in March, the number of trucks increased along with the number of express deliveries.

### 3.2 Calculation of carbon emission data for different models of goods vehicles in different months

The four types of trucks are classified based on their GVW values. Each type is further categorized according to the range of GVW given in GB 30510-2018. The heavy trucks are then divided into four categories. The trucks are categorized into different types based on their weight. Heavy trucks are classified into four types: medium trucks are divided into three categories, and light trucks are divided into two categories. The relevant data and analyses have been processed and analyzed according to the following classification: medium-duty trucks are divided into three categories (category I, category II, and category III), while light-duty trucks are divided into two categories (category I and category II).

Tables 4, 5, 6, and 7 list the number of vehicles and carbon emissions for different types of goods vehicles each month, using the 'Carbon Emission Factor Method corresponding to Load Weight' mentioned above.

**Table 4.** Carbon Emissions of Different Models of Goods Vehicles in the First Quarter

| Carbon Emissions of Different Van Models in the First Quarter | | | |
|---|---|---|---|
| | January | February | March |
| Carbon emissions from minivans (kg) | 14538.11 | 20428.13 | 31273.87 |
| Carbon emissions from Class I light goods vehicles (kg) | 29687.25 | 26971.13 | 57693.89 |
| Carbon emissions from Class II light goods vehicles (kg) | 20738.22 | 23891.13 | 49399.16 |
| Carbon emissions from Class I medium goods vehicles (kg) | 37818.07 | 21327.41 | 42629.58 |
| Carbon emissions from type II medium goods vehicles (kg) | 37467.88 | 26488.16 | 49146.25 |
| Carbon emissions from medium goods vehicles, category III (kg) | 40108.05 | 35596.89 | 63342.59 |
| Carbon emissions from Class II heavy goods vehicles (kg) | 572193.74 | 529471.34 | 772778.83 |
| Carbon emissions from Class III heavy goods vehicles (kg) | 1042469.78 | 975984.45 | 1535459.06 |
| Carbon emissions from four categories of heavy goods vehicles (kg) | 4655074.49 | 3669441.93 | 7321880.73 |

**Table 5.** Carbon Emissions of Different Models of Goods Vehicles in the Second Quarter

| Carbon Emissions of Different Models of Vans in the Second Quarter | | | |
|---|---|---|---|
| | April | May | June |
| Carbon emissions from minivans (kg) | 28544.57 | 49932.38 | 58188.13 |
| Carbon emissions from Class I light goods vehicles (kg) | 36004.53 | 33605.78 | 41546.72 |

| | | | |
|---|---|---|---|
| Carbon emissions from Class II light goods vehicles (kg) | 36728.57 | 31844.36 | 39827.43 |
| Carbon emissions from Class I medium goods vehicles (kg) | 42813.61 | 51878.33 | 115141.00 |
| Carbon emissions from type II medium goods vehicles (kg) | 45483.75 | 61120.30 | 113572.77 |
| Carbon emissions from medium goods vehicles, category III (kg) | 56903.51 | 63330.68 | 91702.27 |
| Carbon emissions from Class I heavy goods vehicles (kg) | 1111532.41 | 912274.75 | 1377237.83 |
| Carbon emissions from Class II heavy goods vehicles (kg) | 788992.57 | 780592.43 | 846598.44 |
| Carbon emissions from Class III heavy goods vehicles (kg) | 1560366.20 | 1648123.94 | 1922193.65 |
| Carbon emissions from four categories of heavy goods vehicles (kg) | 5431286.21 | 7110856.74 | 9839458.48 |

**Table 6.** Carbon Emissions of Different Models of Goods Vehicles in the Third Quarter

| | July | August | September |
|---|---|---|---|
| Carbon emissions from minivans (kg) | 53399.68 | 28369.09 | 46538.48 |
| Carbon emissions from Class I light goods vehicles (kg) | 47993.90 | 32417.07 | 32748.47 |
| Carbon emissions from Class II light goods vehicles (kg) | 42609.16 | 36055.73 | 36391.83 |
| Carbon emissions from Class I medium goods vehicles (kg) | 89592.48 | 70013.95 | 72164.63 |
| Carbon emissions from type II medium goods vehicles (kg) | 45483.75 | 61120.30 | 113572.77 |
| Carbon emissions from medium goods vehicles, category III (kg) | 73422.30 | 60103.36 | 60518.58 |
| Carbon emissions from Class I heavy goods vehicles (kg) | 447742.54 | 484891.29 | 472441.93 |
| Carbon emissions from Class II heavy goods vehicles (kg) | 375109.83 | 317775.06 | 346789.96 |
| Carbon emissions from Class III heavy goods vehicles (kg) | 853630.41 | 639931.03 | 774794.70 |
| Carbon emissions from four categories of heavy goods vehicles (kg) | 1648841.19 | 1141678.19 | 1345730.82 |

**Table 7.** Carbon Emissions of Different Models of Goods Vehicles in the Fourth Quarter

| Carbon Emissions of Different Van Models in the Fourth Quarter | | | |
|---|---|---|---|
| | October | November | December |
| Carbon emissions from minivans (kg) | 27232.42 | 81886.15 | 324943.26 |

| | | | |
|---|---|---|---|
| Carbon emissions from Class I light goods vehicles (kg) | 30728.63 | 26280.16 | 36264.28 |
| Carbon emissions from Class II light goods vehicles (kg) | 32778.33 | 24551.72 | 39595.78 |
| Carbon emissions from Class I medium goods vehicles (kg) | 36656.67 | 26245.92 | 42670.45 |
| Carbon emissions from type II medium goods vehicles (kg) | 46514.87 | 35261.33 | 57882.18 |
| Carbon emissions from medium goods vehicles, category III (kg) | 100624.04 | 93546.96 | 107590.25 |
| Carbon emissions from Class I heavy goods vehicles (kg) | 169221.46 | 166787.93 | 203499.58 |
| Carbon emissions from Class II heavy goods vehicles (kg) | 177674.53 | 150218.16 | 351803.68 |
| Carbon emissions from Class III heavy goods vehicles (kg) | 547522.33 | 643886.16 | 1368487.09 |
| Carbon emissions from four categories of heavy goods vehicles (kg) | 858315.43 | 825915.85 | 1737620.49 |

The data analysis reveals significant differences in carbon emissions among various types of trucks. Heavy-duty trucks, with the largest load capacity, have the highest carbon emission factor and produce the highest carbon emissions. This finding aligns with the situation, as heavy trucks consume more fuel and travel longer distances, generating higher carbon emissions.

Carbon emissions for light goods vehicles peaked in March of the year's first half, possibly due to the resumption of logistics activities after the Chinese New Year holiday. Logistics activities were suspended during the holiday, leading to stagnation in the industry. After the holiday, logistics companies needed to resume normal operations to meet market demand quickly. Logistics activities increased in March, increasing carbon emissions from light-duty trucks.

Their carbon emissions reach their highest value in June for medium- and heavy-duty trucks, which may be related to the high level of business activities in June and the peak travel season. June is the most active month of the year regarding business activities, which increases the transportation demand for medium and heavy trucks. June is also the peak travel season, resulting in higher traffic volume and passenger numbers throughout the year. The use of medium and heavy goods vehicles results in increased carbon emissions. Additionally, the hot weather in June leads to a significant increase in national energy consumption. Xinjiang, an essential energy-exporting region in China, chooses to transport large amounts of energy using medium and heavy trucks to meet the nation's energy consumption needs, which is one of the reasons for the increase in carbon emissions from medium- and heavy-duty trucks.

# 4 SUMMARY AND RECOMMENDATIONS

This study measured the carbon emissions of highway sections at Xinjiang G30 Yandun Toll Station using the 'Carbon Emission Factor Method Corresponding to Load Weight.' The study analyzed the total carbon emissions of different types of trucks in different months and drew the following conclusions:

1. In this highway section, heavy trucks accounted for the most significant proportion of all trucks, with micro, light, and medium trucks accounting for only 2%, 2%, and 4% of the total vehicles, respectively. Carbon emissions were calculated for all types of trucks using the 'Carbon Emission Factor Corresponding to Load Weight Method.'
2. The carbon emissions of all types of trucks increased every month during the first half of the year when measured using the 'Carbon Emission Factor Corresponding to Load' method. However, emissions gradually decreased during the second half of the year.
3. The trucks were categorized by month, and their carbon emissions were measured using the 'Carbon Emission Factor Corresponding to Carrying Capacity Method.' The results showed that light trucks emitted the highest amount of carbon in March, while medium- and heavy-duty trucks emitted the highest amount in June.
4. Based on these conclusions, decarbonization efforts in transportation construction in Xinjiang should focus on three main areas.

1. Improving the Transportation Energy Mix in Xinjiang In underdeveloped energy resource exporting regions like Xinjiang, traditional petroleum products such as diesel and gasoline are still the primary sources of carbon emissions from medium and heavy-duty trucks, despite the multifrequency nature of climate change and the region's varying climates, which makes it challenging to move traffic on high-speed road sections, indirectly increasing carbon emissions. So, clean energy should be promoted in areas with good highway access.
2. The modern transportation industry should be developed further. The region's transportation infrastructure is insufficient to handle the sudden increase in demand after the Spring Festival. It is necessary to accelerate the construction of additional modes of transportation, which will help reduce the average carbon emissions of goods and improve overall transportation efficiency.
3. While optimizing the industrial structure, the region should rationally allocate the development of each local tertiary sector of the economy to ensure the efficiency of economic growth. While optimizing the industrial structure, the region should rationally allocate the development of each local tertiary sector of the economy to ensure the efficiency of economic growth. While optimizing the industrial structure, the region should rationally allocate the development of each local tertiary sector of the economy to ensure the efficiency of economic growth. As an agricultural, energy, and mineral-exporting region, the region should stabilize operations while gradually promoting economic growth.

This study has achieved specific results and analyzed the trends to give recommendations through the measurement of data and rational Analysis of data, but this study still has some limitations:

1. Limitations of the research data: The research data for this experiment was collected from the Xinjiang road section over one year. The sample size, however, is small, which limits the scope of the research results and prevents them from reflecting the overall situation.
2. Limitations of the research methodology: This study employed only one method to measure the transportation carbon emissions of each category of trucks, which limited the accuracy of the results and their generalizability. Using multiple methods to measure and validate the emissions would have improved the accuracy of the results.
3. Limitations of the research theory: The study's conclusions are limited to the Xinjiang region due to the use of carbon emission factors specific to that area.
4. Limitations of the study's external validity: The study focused solely on the transportation sector in the region, which limits its external validity to other industry sectors.

## ACKNOWLEDGEMENT

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